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Toward a Green Internet
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in their fruit production. This pattern was generally consistent across a great variety of the most important pollination-dependent crops. The benefit associated with wild bees did not depend on whether or not honeybees were present. Thus, conservation of wild bee diversity will be paramount even when managed honeybees are used.

The two studies (*6*, *7*) highlight the effects of environmental change on pollinator-plant interactions and the risks of putting all our eggs in one basket for pollination. Garibaldi *et al*.'s finding that fruit set increased and became less variable with pollinator diversity, independently of visitation by honeybees, highlights the importance of in situ biodiversity for food production. This challenges the validity of land-sparing conservation approaches (*12*), which advocate the protection of biodiversity only outside farmed areas, and the further intensification of agricultural land use. Above all, the studies show conclusively that biodiversity has a direct measurable value for food production and that a few managed species cannot compensate for the biodiversity on which we depend.

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COMPUTER SCIENCE

Toward a Green Internet

Methods for energy efficiency savings will be needed to meet the growing demands of increasing Internet usage.

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Information and communication technology (ICT) has been extensively used to monitor energy use in a variety of applications. However, the use of ICT itself has led to huge increases in energy consumption. Today, we are witnessing a rise of energy costs, customer increase, more on-demand services using cloud architectures, mobile Internet, a diffusion of broadband access, and a growing number of services offered by internet service providers (ISP). Consequently, energy efficiency is quickly becoming a high-priority issue for the Internet.

Telecom companies such as Telecom Italia used over 2 terawatt hours (TWh) in 2006 (about 1% of the entire Italian energy demand), increasing by ~8% compared with 2005 and ~12% in 2004 (*1*, *2*). Comparable numbers were reported by Telecom France and British Telecom, by Verizon in the United States, and by NTT in Japan. In Germany, 20% of Internet energy usage was due to cooling systems. In 2005, European Internet operators had an overall network energy requirement equal to 14 TWh, increasing to 21 TWh in 2010, and projected to rise to 36 TWh in 2020 if no green network technologies are embraced. Moreover, the world's data centers consumed over 270 TWh in 2012; it is estimated that they will consume 19% more energy in the next 12 months than they have in the past year (*3*). The cost of new equipment has been overtaken by the cost of the required power and cooling infrastructure and will soon be exceeded by the lifetime energy costs (*4*).

Although Internet traffic volume doubles every 3 years, the increase in usage has not been matched by a similar increase in network energy efficiency. Current networks, devices, links, and data centers are provisioned with hardware and software designed for peak loads that do not include any power management capabilities. As a consequence, the overall power consumption remains more or less constant for differing Internet traffic levels even while peak loads rarely occur.

As the Internet evolves, it is apparent that energy efficiency needs to be addressed.

Over the past 3 years, a number of international research projects (*5–7*) have been initiated, with specific efforts including methods to redesign the power management features of network devices to improve efficiency (*8*, *9*). Two of the most exciting new techniques are smart standby (*10*) and dynamic frequency scaling (also known as CPU throttling). The former will allow unused parts of a network device to be put into very low power states, where only very basic functionalities are performed. This method is key for reducing energy consumption because it will allow switching some portion of the network to a sleep mode in a smart and effective way.

Dynamic frequency scaling allows us to trade off the energy consumption and processing capacity of internal blocks while satisfying the current traffic load and quality of service constraints. This ensures that when the
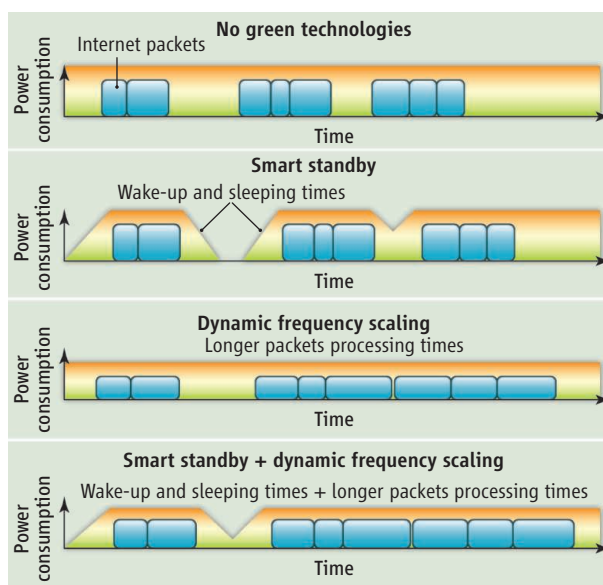
Improving efficiency. Packet service times and power consumption when no green technologies are applied, with only smart standby, with only dynamic frequency scaling, and with both smart standby and dynamic frequency scaling.

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system is under partial load, parts of it can be throttled to decrease the power consumption without a reduction of overall performance.

The power consumption and the packet service times can be depicted for different scenarios (see the figure). When smart standby is used, different idle states are usually designed by selectively turning off an increasing number of hardware units. This leads to a reduction of the energy consumption during idle times; however, longer times are needed to wake up all the hardware. Similarly, dynamic frequency scaling hardware support is designed by preselecting a set of operating clock frequencies whose values are submultiple of the maximum one and that provide silicon stability. Dynamic frequency scaling causes a stretching of packet service times, while the sole adoption of smart standby introduces an additional delay in packet service, due to the wake-up times. Finally, the joint adoption of both energy-aware capabilities may not lead to outstanding energy gains because dynamic frequency scaling causes larger packet service times and, consequently, shorter idle periods.

The next generation of network devices will include local control policies (8) that will be able to set up and synchronize their energy-aware capabilities. For example, analytical models have been defined to allow designers of green network devices to calculate in advance the temperature statistics of a device and decrease it when possible (11). Reduction of the average temperature allows designers to reduce the hardware size and the size of passive and active cooling systems and thus reduce energy consumption.

New algorithms for network-wide control, both distributed and centralized, are starting to take green metrics into account. For example, a possible distributed solution currently builds upon link-state protocols and puts links in an Internet protocol–based network into sleep mode at appropriate times (12). This method allows limiting the amount of shared information, avoiding explicit coordination among nodes, and reducing the problem complexity. Thus, the switch-off decision takes the current load of links and the history of past decisions into account.

With such practices spreading into industry, large companies are now building energy-efficient data centers for minimizing data-center power costs (13). Moreover, measurement of servers in a production data center from both power and performance reveal that most servers are underused and have similar activity patterns across the days of the week (14).

The fundamental problem of greening the Internet is to strike a fine balance between the demands of performance and the limitations of energy usage. New research initiatives in energy optimization have revealed several aspects of the Internet that can be streamlined. Addressing the issues of energy efficiency will allow us to draw deeper conclusions on how new network systems can be smarter and more effective.

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NEUROSCIENCE

Neural Stem Cells, Excited

Electrical activity in the adult mammalian brain triggers neurogenesis.

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Although the brain is generally considered a terminally differentiated organ, new nerve cells are made every day through a process called "adult neurogenesis," which occurs in specialized regions like the hippocampal dentate gyrus (1). Stem cells in the brain sample electrical signals (activity) from neighboring neurons, deciding which genes to express and which signaling pathways to launch toward developing their own neuronal identity. Why would stem cells be able to respond to exogenous neuronal electrical activity, which can be considered a highly specialized function? Indeed, it seems counterintuitive insofar as one of the defining functions of all stem cells is to actively maintain the undifferentiated state.

The central feature of brain function is the transmission of electrical signals from neuron to neuron in complex networks and circuits. How neurons "listen and talk" to each other is determined by cell identity—that is, which genes (e.g., encoding receptor systems or neurotransmitter biosynthesis pathways) are expressed by an individual neuron and which are not. The complexity of this information exchange is staggering because billions of neurons, falling into distinct molecular and cellular phenotypes based on their gene expression patterns, are communicating with each other at the same time.

Cultured neural stem/progenitor cells isolated from rodent hippocampus can respond to external neural activity and differentiate into neurons (2). This activity-dependent neurogenesis requires Ca^{2+} channels and receptors for the neurotransmitter *N*-methyl-D-aspartate (NMDA) on proliferating stem/progenitor cells, and hence is called "excitation-neurogenesis coupling." In vivo, type 2 stem/progenitor cells [expressing nestin, a protein marker for neural stem/progenitor cells; they also morphologically lack projections (dendrites and axons) from the cell body] express receptors for γ-aminobutyric acid (GABA) and can be activated by this chemical when released by nearby active neurons (3, 4). A possible mechanism for excitation-neurogenesis coupling is GABA-mediated depolarization (4), previously

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